Isobaric bubble growth and collapse in magma

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Bubble growth forces magma to rise in volcanic conduits, produces overpressure within the conduit and leads to fragmentation of the melt during explosive eruptions. The three main mechanisms controlling the growth of bubbles in melts are: (1) decompressive expansion, (2) water diffusion/exsolution related to oversaturation and (3) bubble coalescence. Magma can experience isobaric conditions as it stagnates in a magma chamber, lava dome or post-eruptive pyroclast. In all these instances, water may diffuse in and out of bubbles despite negligible decompression. After the melt solidifies, water gradients related to bubbles formed by dissolution and/or resorption, are capable of preserving these periods of magma stagnation.

Here we present high-resolution water distribution data of isobaric bubble growth experiments in natural rhyolitic samples. Bubble free aphanitic rhyolite was heated to 950℃ and volume changes were visually tracked. The samples were either just kept at 950℃ for 3-24 h or were subsequently cooled to 850℃ and kept for an equal amount of time before they were cooled to room temperature.

Samples show an initial volume increase of 140% - 450%, and later deflate by about 5% of the maximum volume. Bubble sizes in the samples range between 10 μm to 1 mm. The surface of the sample consists of a thin skin of bubble-free glass that prevents the sample from deflating through a permeable network. Water gradients show a decrease of water content across this rim to the outer surface of the sample. The background water content of the glass ranges between 0.1-0.5 wt. %. Water content either increases or decreases around bubbles. If the samples are heated to 950℃ for only short timescales of 2-3h, water contents decrease towards the surface of the bubble. No systematic gradients develop around bubbles in samples that were held for 24h at 950℃. Many bubbles in samples that were cooled by 100℃ and kept at this lower temperature show an increase of water in the glass towards the surface of the bubbles.

This shows that water diffuses into vesicles during growth until equilibrium bubble size is reached when volatiles neither exsolve nor resolve around individual bubbles. Equilibrium bubble size, however, can vary depending on local quantities of water. The equilibrium is reached after $\leq$24 h at temperatures of 950℃ and diffusion homogenizes water contents and any gradients that remain from stages of bubble growth. If the glass is subsequently cooled, the solubility of water increases and it can get resorbed into the glass.

Our experiments allow us to track the volatile diffusion around bubbles, showing the thermal history and degassing patterns in almost completely degassed samples. This approach will serve as an important tool for the estimation of timescales and processes that control effusive and explosive volcanic eruptions.